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GENERATION AND CYCLOADDITION REACTIONS OF SUBSTITUTED 2-NITRO-1,3-DIENES.

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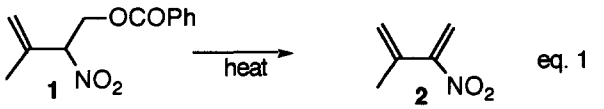
Abstract: 4-Acyloxy-2-substituted-3-nitro-1-butenes have been utilized as convenient precursors of the corresponding 2-nitro-3-substituted-1,3-butadienes which could be easily generated *in situ* by heating or by treatment with sodium acetate and trapped by suitable partners such as methyl acrylate, cyclopentadiene or ethyl vinyl ether. The expected cycloadducts are regiochemically formed by reaction with methyl acrylate, while the initially formed adducts with cyclopentadiene underwent thermal Cope or hetero-Cope rearrangements leading to the formation of nitro-substituted bicyclic compounds. The thermal rearrangement of the oxazine-N-oxides resulting through hetero Diels-Alder reaction with ethyl vinyl ether as cycloaddition partner led to the formation of 1,2-oxazole-3-propionaldehydes. The wide variety of highly functionalized carbocyclic and heterocyclic compounds generated through the use of these multi-coupling reagents provided useful synthons for the construction of simple and complex natural compounds.

The synthesis of dienes in general and the application in the Diels-Alder reaction in particular is still an important challenge in synthetic organic chemistry. Since its discovery, this cycloaddition reaction has been one of the most powerful methods for the construction of cyclic systems, and the secret of its longevity has been the possibility for absolute stereochemical control at up to 4 contiguous centres in one step through a suitable choice of the interacting diene and dienophile. The presence of electron-withdrawing substituents on either of the cycloaddends has attracted particular attention due to their ability to induce a high degree of diastereoselectivity.

The introduction of electron-withdrawing groups into dienes permits regiocontrolled synthesis of a great variety of highly functionalized cyclohexene systems. Moreover, an electron-withdrawing group could play a crucial role in carbon-carbon bond forming reactions and its synthetic utility could be enhanced if it could undergo efficient functional group interconversions including its removal.

Therefore, it is not surprising that, among many electron-withdrawing substituents for the activation of dienes, a nitro group has been frequently chosen for incorporation in both partners of a cycloaddition reaction.[1] A great deal of attention has been recently devoted to 1-nitro-1,3-dienes,[2] which can be efficiently prepared and their chemistry sufficiently explored. In contrast, the synthetic potential represented by 2-nitro-1,3-dienes has not been fully exploited. The procedures currently available for their generation include thermolysis[3] of 2-nitro-1-acetoxy-alk-3-enes and thermal cheletropic extrusion of sulfur dioxide[4] from 4-nitro-3-sulfolenes 1,1-dioxide. Moreover, Bäckwall et all.,[5,6] after having initially demonstrated the possibility of trapping 2-nitro-1,3-dienes as monoepoxides by oxidative elimination of selenium from nitroselenated adducts, were later able to promote a base-catalyzed elimination of PhSeH from the same adducts with the *in situ* generation of nitrodienes, which were employed to obtain [4+2] heterocycloadducts with enamines via a multistep reaction. It was apparent that the use of 2-nitrodienes has been likely limited both by the lack of convenient protocols for their preparation and

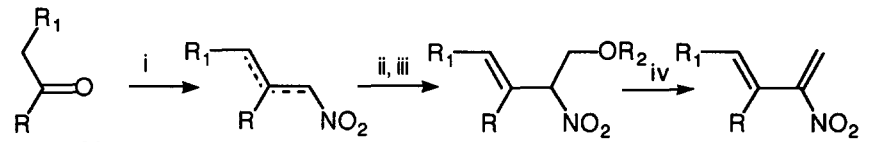
by their propensity to dimerize. In the course of our synthetic efforts in the area of excitatory amino acids of the kainoid family,[7] we discovered (eq. 1) that the required 2-nitro-3-methyl-1,3-butadiene **2** could be easily generated *in situ* by heating or by treatment with sodium acetate of the nitro benzoate **1**, taking part as the electrophilic counterpart of a suitable nitrogen nucleophile in a tandem Michael reactions sequence leading to the construction of the featuring tri-substituted pyrrolidine ring system .



1 **2** eq. 1

In order to extend the scope and the applicability of this facile transformation, we have developed a simple methodology for preparing compounds **6a-h**. Thus, the Knoevenagel condensation between ketones **3a-h** and nitromethane gave the unsaturated nitro compounds **4**, which may have allylic nature (entries a,c,g,h), vinylic (entry d) or a mixture of both (entries b, d, e, f). Interestingly, all these compounds underwent a sodium methoxide-catalyzed reaction with paraformaldehyde to produce in satisfactory overall yield the allylic β-nitroalcohols **5a-h**, easily transformed by standard chemistry to the corresponding acetate esters **6a-h**, which represent the effective synthetic equivalents of the corresponding nitrodienes **7a-h**, being easily generated *in situ* by heating or by treatment with sodium acetate.

Scheme I



3 (a-h) **4 (a-h)** **5 (a-h)** R_2 = H **6 (a-h)** R_2 = Ac **7 (a-h)**

Reagents : i, CH_3NO_2, N,N-diethylethylenediamine; ii, $(CH_2O)_3$, MeONa; iii, Ac_2O; iv, AcONa, heat.

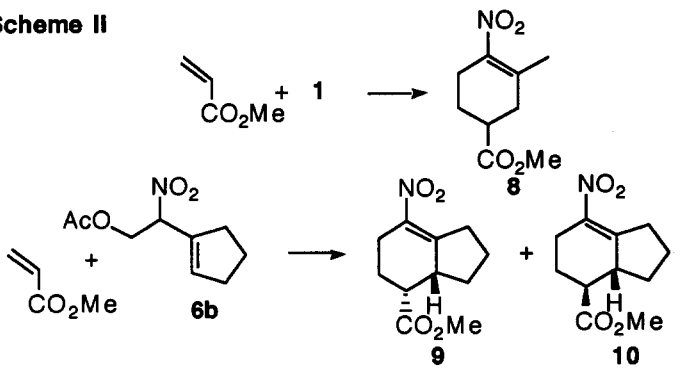
	R	R_1	
a	CH_3	CH_3	**3a** = 2-Butanone
b	$-(CH_2)_3-$		**3b** = Cyclopentanone
c	$-(CH_2)_4-$		**3c** = Cyclohexanone
d	Ph	H	**3d** = Acetophenone
e	pNO_2Ph	H	**3e** = p-Nitroacetophenone
f	pCH_3OPh	H	**3f** = p-Methoxyacetophenone
g	$-oPh(CH_2)_2-$	H	**3g** = α-Tetralone
h	$pCH_3O-oPh(CH_2)_2-$	H	**3h** = 6-Methoxy-1-tetralone

With a convenient source of substituted 2-nitro-3-substituted-1,3-dienes in hand, the stage was set to investigate their behaviour in cycloaddition chemistry.

Cycloaddition with methyl acrylate.

Reactions between dienes and dienophiles, both incorporating electron-attracting substituents, are rather uncommon. The first problem we faced was finding the best experimental conditions to perform the Diels-Alder reaction, which must be compatible with the propensity of the diene to dimerization. We found that cycloaddition proceeded satisfactorily by treating the nitrobenzoate **1**, precursor of the nitrodiene **2**, with methyl acrylate in the presence of sodium acetate in benzene solution at 120°C. As far as the regiochemistry of the process is concerned, the formation of the cycloadduct **8** as the sole reaction product indicated that the nitro group is a much more powerful *para*-directing element than the alkyl group in controlling the regioselectivity of the Diels-Alder reaction, in line with the predictions of the frontier orbital theory.

Scheme II

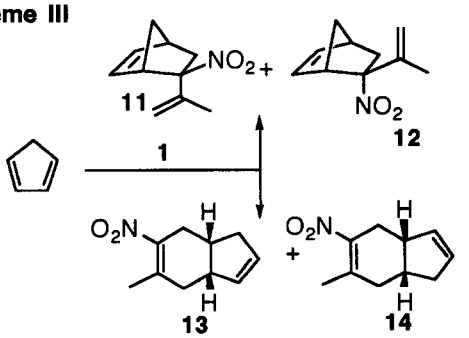


In order to gain more information about the stereochemistry of the process, we carefully studied the reaction of methyl acrylate with **6b**, used as the precursor of the more complex nitrodiene **7b**, under the same experimental conditions. Purification of the reaction mixture through silica gel column chromatography led to the separation of the two cycloadducts **9** and **10**. The diastereomeric ratio (76:24) has been assigned on the basis of the ^{1}H NMR integration of the methoxyl protons at 3.6 and 3.7 ppm, the preferred *cis* stereochemistry being consistent with the *endo* rule of Diels-Alder reactions.

Cycloaddition with cyclopentadiene.

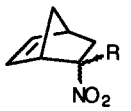
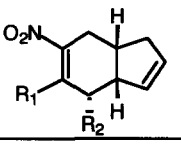
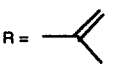
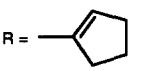
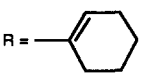
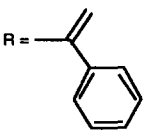
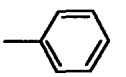
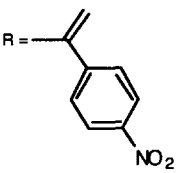
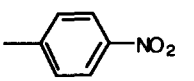
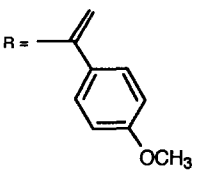
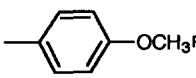
To further explore the reactivity of nitrodienes, we investigated the behaviour of the nitrodiene **2**, taken as a simple model, as a partner in cycloadditions, where it could act as a diene or as a dienophile.

Scheme III



To this end we examined its reaction with cyclopentadiene, as shown in the Scheme III. Thus, the reaction of nitrobenzoate **1**, used as the precursor of **2**, with cyclopentadiene in the presence of sodium acetate at 80°C in benzene, led to the formation of a mixture of three cycloadducts. Flash chromatographic purification furnished an unseparable *endo-exo* mixture of **11** (19.2%) and **12** (44.8%), together with the more polar compound **13** (36%).

Table I

Nitrodiene precursor		
1	11 + 12 R = 	13 $R_1 = CH_3$ $R_2 = H$
6b	15 R = 	16 $-R_1-R_2- = -(CH_2)_3-$
6c	17 R = 	18 $-R_1-R_2- = -(CH_2)_4-$
6d	19 R = 	20 R_1 =  $R_2 = H$
6e	21 R = 	22 R_1 =  $R_2 = H$
6f	23 R = 	24 R_1 =  $R_2 = H$

While the formation of **11** and **12**, originating by the Diels-Alder reaction between the cyclopentadiene and the nitrodiene **2**, acting as the diene and dienophile counterparts respectively, was easily predictable, it seemed

less easy to account for the formation of a single cycloadduct deriving by a cycloaddition process where the same two cycloaddends had switched the roles of their partnership, with the diene behaving as the dienophile.

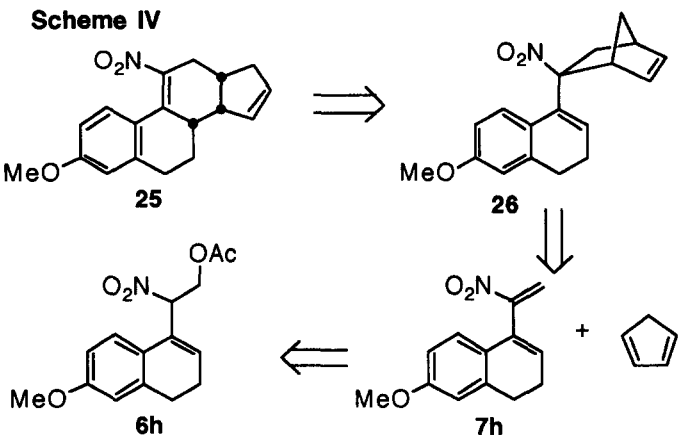
Moreover, the lack of the isomeric bicyclic compound **14** and the high regiospecificity observed are rather puzzling, and certainly these findings could not be accounted for as indicated in the Scheme III, the origin of the observed high selectivity requiring a much more complex explanation.

We suggest a Cope rearrangement of **11** as the first event leading to the formation of **13**, also accounting for by the experimentally observed poorer yield of the *endo* product **11** in comparison to the *exo* product **12**. Moreover, heating the mixture of **11** and **12** in toluene for three days afforded exclusively the rearranged product **13**.

Further examples of the reaction between cyclopentadiene and the nitrodiene precursors confirmed this trend of reactivity as summarized in Table I, in which are collected all cycloadducts and the rearranged products.

Based on these results, we were attracted by the possibility of a straightforward assemblage of the steroid skeleton by applying the synthetic sequence retrosynthetically depicted in the Scheme IV, which simply called the Diels-Alder reaction of nitrodiene **7h** with cyclopentadiene, followed by a Cope rearrangement of the derived cycloadduct **26**.

Scheme IV

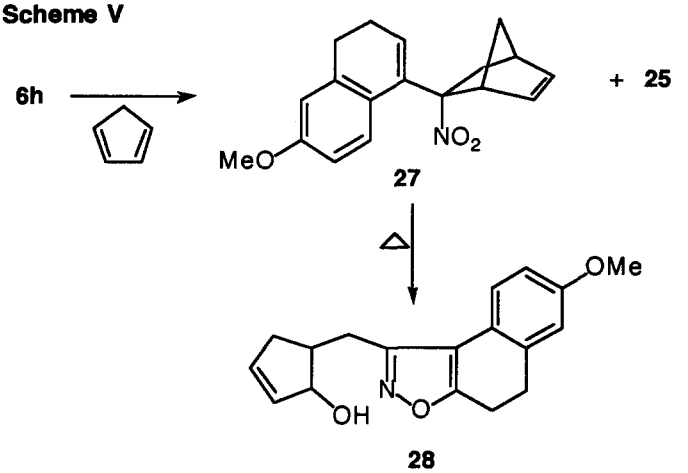


In order to test the feasibility of the scheme, a mixture of the acetyl derivative **6h**, as the synthetic equivalent of **7h**, and cyclopentadiene was refluxed in benzene solution in the presence of sodium acetate for 24h.

Column chromatographic purification of the reaction mixture led to the isolation of the cycloadduct **27** as the main reaction product in 52% yield, together with a small quantity (7% yield) of the required **25**, the product deriving by sigmatropic rearrangement of **26**.

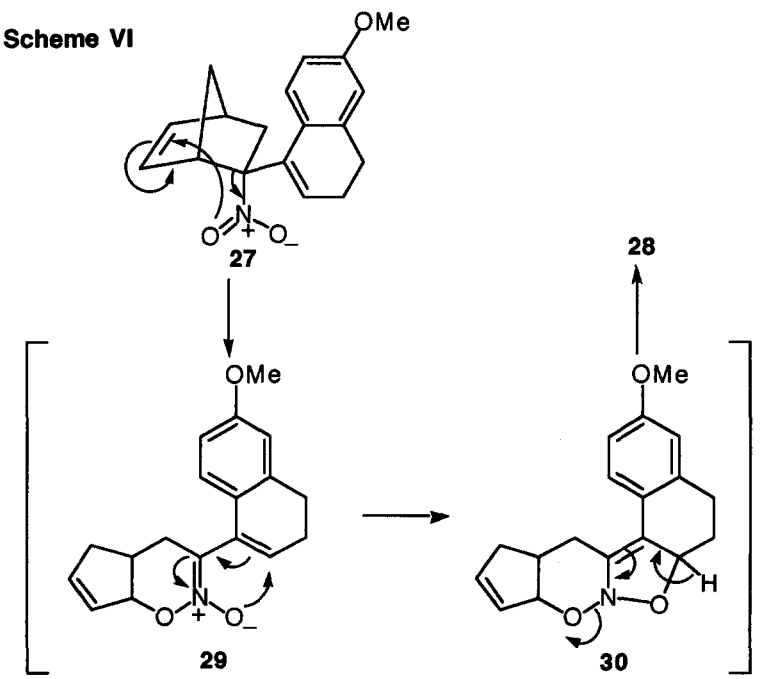
The structures of **25** and **27** were established by IR and ^{1}H NMR analyses. Moreover, the *endo* arrangement of the nitro group in the cycloadduct **27** could also be inferred by its reluctancy to undergo Cope rearrangement to give **25**, even after prolonged heating, which, unexpectedly, promoted the transformation of **27** into the isoxazole derivative **28**.

Scheme V



The formation of **28** is likely to proceed *via* generation of the nitronate **29**, the nitro group participating to a Cope-like rearrangement, followed by an intramolecular Michael addition to give the nitroso acetal **30**, which finally underwent thermal rearrangement to produce the isoxazole **28**, as depicted in the Scheme VI.

Scheme VI



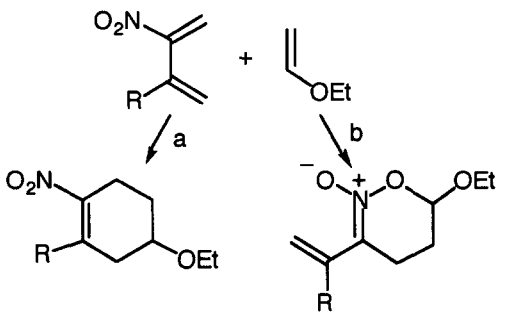
The formation of a single regioisomer permitted also to rule out the alternative mechanism, i.e. the formation of **29** by a hetero Diels-Alder reaction between the nitrodiene **7h** and cyclopentadiene. The abnormal chemical behaviour of nitrodiene **7h** might be conceivably explained through the strongly favoured formation of the

isomer **27** in the *exo-endo* mixture of **26** and **27**, the latter undergoing preferably the unusual sigmatropic rearrangement rather than a difficult retro Diels-Alder process.

Cycloaddition with ethyl vinyl ether.

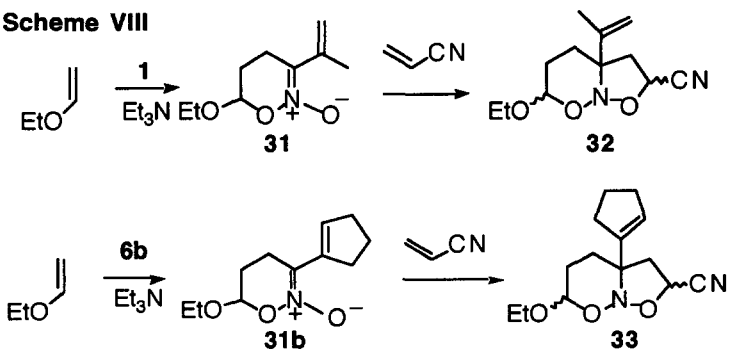
Cycloaddition reaction of nitrodienes with the moderately electron-rich ethyl vinyl ether has been a further topic of our methodological exploration of their reactivity, following the two pathways depicted in Scheme VII.

Scheme VII



While a normal Diels-Alder reaction as already described for methyl acrylate could take place in the first case (path a), a hetero Diels-Alder occurred in the second case (path b) affording a cyclic nitronate, in agreement with the recently disclosed and amply documented chemistry of nitroalkenes.[1,8] In order to elucidate the reaction course, the nitroesters **1** and **6b**, used as synthetic equivalents of the nitrodienes **2** and **7b**, have been treated with ethyl vinyl ether in the presence of triethylamine at room temperature.

Scheme VIII

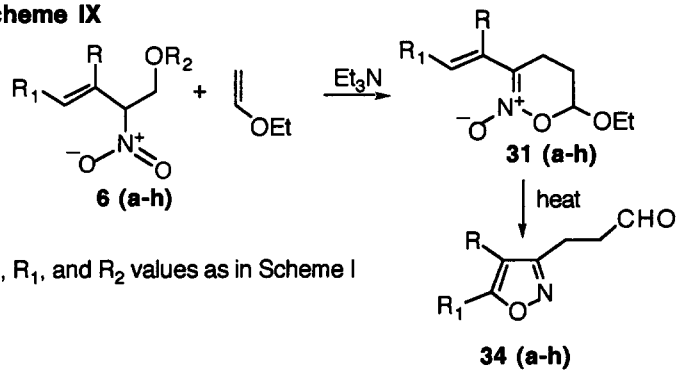


Analytically pure cyclic nitronates **31** and **31b** were isolated in good yields (87 and 89% yield respectively). The nitronate structures could be assigned either chemically or on the basis of ^{1}H NMR (presence of the acetal methine proton at 5.68 ppm) and IR (-C=N stretching band at 1609 cm^{-1}), as already reported in the literature.[9]

Thus, treatment of **31** and **31b** with acrylonitrile at 70°C in DMF led to the formation of **32** and **33** respectively as unseparable mixture of diastereomers. Their formation is consistent with the reactivity of nitronates as electron-rich 1,3 dipoles, as reported by Tartakovskii[10] and more recently by Denmark.[11]

Following the same protocol we have prepared a number of dihydrooxazine-N-oxides, which are collected in the Scheme IX.

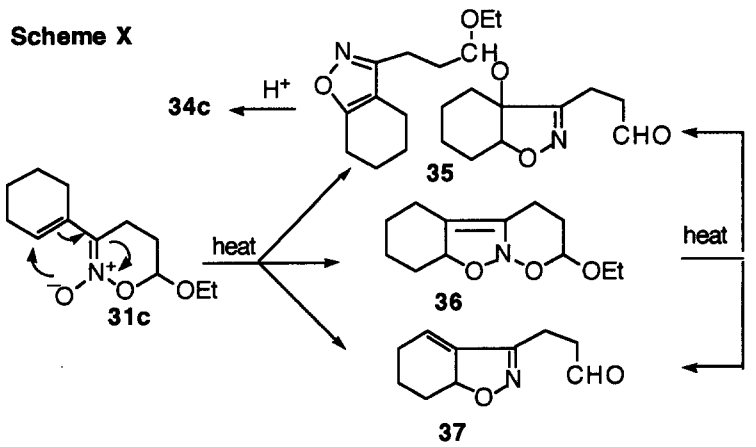
Scheme IX



R, R_1, and R_2 values as in Scheme I

While the synthetic potential of dihydrooxazine-N-oxides has been widely examined subjecting them to a variety of transformations including hydrolytic bond cleavage following the Nef protocol,[12] reduction with titanium chloride (III),[13] with zinc in acetic acid,[14] with lithium aluminum hydride or catalitically,[15] oxidation with ruthenium tetroxide,[14] little information is available in the literature about the thermal behaviour of nitronates, although Tohda et al.[9] have observed the heterolytic cleavage of O(1)-C(6) bond of the oxazine nucleus. Interestingly, heating **31a** in refluxing toluene we obtained the isoxazole aldehyde **34a** as a sole product in acceptable yield.

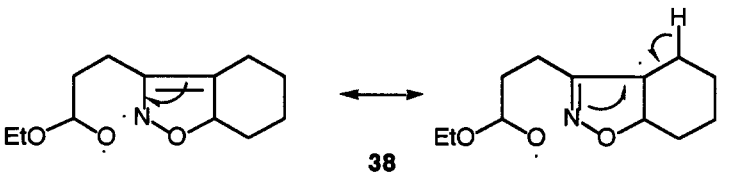
Scheme X



Analogous results have been obtained with all nitronates **31(b-h)** but **31**, which unexpectedly failed to undergo this transformation. The structures of the aldehydes **34(a-h)** have been assigned on the basis of spectroscopic analyses (IR, ^{1}H NMR,^{13}C NMR). Interestingly, the possibility of separing by silica gel chromatography the three products **35**, **36** and **37**, formed in 58, 22 and 20% yield respectively by refluxing in toluene solution the nitronate **31c**, allowed us fortuitously to understand the course of the observed thermal transformation of nitronates. In fact, **36** could be converted by heating into a mixture of **35** and **37**, while acid treatment of **35** gave the isoxazole aldehyde **34c**. These results led us to suggest that the formation of the isoxazole aldehydes could take place through a radical mechanism. Although a direct proof of the radical

formation could not be given, the isolation of the dimerization product **35** makes the intermediacy of radical species highly probable.

Thus, an initial intramolecular Michael addition of nitronate **31c** to the nitrosoacetal **36**, followed by the homolytic cleavage of the O-N bond of the oxazine ring, produce the diradical **38**, which could either dimerize to **35** or lead to **37**, the double bond being formed by hydrogen elimination.



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In summary, 2-nitro-3-substituted-1,3-dienes can readily be prepared by the eliminative route shown in Scheme I. These activated dienes are efficient partners in cycloaddition reactions and the resulting usual or rearranged cycloadducts provide a convenient source of highly functionalized synthons for some classes of organic compounds. The generalization of these findings and the use of these dienes for the synthesis of various carbocyclic and heterocyclic compounds are the object of ongoing investigations.

Acknowledgment. We gratefully acknowledge Consiglio Nazionale delle Ricerche (Roma) and Ministero Pubblica Istruzione (Fondi 40% and 60%) for generous support.

Experimental.

General remarks. Melting points were determined on a Büchi-Tottoli apparatus and are uncorrected. Infrared (IR) spectra were measured on a Perkin-Elmer Model 297. Nuclear magnetic resonance (^{1}H NMR) spectra were recorded on a Bruker AC-200 spectrometer for solutions in $CDCl_3$ unless otherwise noted and peak positions are given in parts per millions downfield from a tetramethylsilane as an internal standard. Coupling constants are given in Hz. Organic solutions were dried over anhydrous magnesium sulfate and evaporated with a rotary evaporator. Light petroleum refers to the fractions boiling range 40-60 °C and ether to diethyl ether. Flash-chromatography was carried out with Merck silica gel (230-400 mesh). All reactions were carried out under N_2 or Argon atmosphere. Elemental analyses were effected by the microanalitical laboratory of Dipartimento di Chimica, University of Ferrara.

Preparation of the nitroolefines 4(a-h). General procedure: a solution of the carbonyl compounds **3(a-h)** (0.2 mmol) and nitromethane (0.8 mmol) in dry benzene (50ml) containing N,N-diethylethylendiamine (30mmol) was heated at reflux with a Dean-Stark trap until complete removal of water. The cooled solution was washed with 5% aqueous HCl, dried, evaporated in vacuo and purified by flash chromatography.

(E) and (Z) 2-Methyl-1-nitro-2-butene 4a. Reaction time: 21h; yellow oil (40%), (eluent: ether / light petroleum 1:4); IR (neat): 1540, 1370 cm^{-1}; ^{1}H NMR: E/Z ratio=18 / 82; 1.74 (s, 3H), 1.76 (s, 3H), 1.70 (s, 3H), 1.73 [(s, 3H) for (E) isomer], 4.83 (s, 2H), 4.97 [(s, 2H) for (E) isomer], 5.73 (m, 1H). Anal. Calcd. for $C_5H_9NO_2$: C, 52.15; H, 7.88; N, 12.17. Found: C, 52.08; H, 7.79; N, 12.11.

1-Nitromethyl-cyclopentene and 1-nitrometilen-cyclopentane 4b. Reaction time: 3.5h; yellow oil (70%), (eluent: ether / light petroleum 0.5:9.5); IR (neat): 1540, 1370 cm^{-1}; ^{1}H NMR: 1.9-2.1 (m, 2H), 2.43 (t, 4H, J=7), 5.03 (s, 2H), 5.93 (s, 1H); IR (neat): 1500, 1350 cm-^{1}; ^{1}H NMR: 1.7-1.9 (m, 4H), 2.4-2.6 (m, 4H), 5.63 (s, 1H). Anal. Calcd. for $C_6H_9NO_2$: C, 56.66; H, 7.14; N, 11.02. Found: C, 56.58; H, 7.10; N, 10.92.

1-Nitromethyl-cyclohexene 4c. Reaction time: 6h; yellow oil (80%), (eluent : ether / light petroleum 1: 3); IR (neat): 1530, 1360 cm^{-1}; ^{1}H NMR: 1.58-1.69 (m, 4H), 2.08-2.13 (m, 4H), 4.81 (s, 2H), 5.94 (s, 1H). Anal. Calcd. for $C_7H_{11}NO_2$: C, 59.54; H, 7.86; N, 9.93. Found: C, 59.44; H, 7.80; N, 9.79.

1-Nitro-2-phenyl-1-propene 4d. Reaction time: 24h; orange oil (20%), (eluent: ether / light petroleum 1:4); IR (neat): 1500, 1330 cm^{-1}; ^1H NMR: 2.65 (d, 3H, J=1), 7.31 (d, 1H, J=1), 7.45 (s, 5H). Anal. Calcd. for $C_8H_9NO_2$: C, 63.55; H, 6.00; N, 9.27. Found: C, 63.48; H, 5.93; N, 9.16.

2-(4-Nitrophenyl)-1-nitro-1-propene and 2-(4-nitrophenyl)-1-nitro-2-propene 4e. Reaction time: 90h, yellow solid, mp 78-80°C (15%), (eluent: ether / light petroleum 1:4); IR ($CHCl_3$): 1500, 1330 cm^{-1}; ^1H NMR: 2.66 (d, 3H, J=1), 7.31 (q, 1H, J=1), 7.60-7.64 (m, 2H), 8.29-8.33 (m, 2H): orange oil; IR (neat): 1550, 1510, 1370, 1350 cm^{-1}; ^1H NMR: 5.41 (s, 2H), 5.76 (s, 1H), 5.98 (s, 1H), 7.58-7.63 (m, 2H), 8.23-8.27 (m, 2H). Anal. Calcd. for $C_9H_8N_2O_4$: C, 51.91; H, 3.88; N, 13.46. Found: C, 51.76; H, 3.69; N, 13.34.

2-(4-Methoxyphenyl)-1-nitro-1-propene 4f. Reaction time: 72h; yellow oil (20%), (eluent: ether / light petroleum 1:3); IR (neat): 1500, 1330 cm^{-1}; ^1H NMR: 2.63 (d, 3H, J=1), 3.85 (s, 3H), 6.93-6.97 (m, 2H), 7.33 (q, 1H, J=1), 7.41-7.46 (m, 2H). Anal. Calcd. for $C_{10}H_{11}NO_3$: C, 62.15; H, 5.74; N, 7.25. Found: C, 62.09; H, 5.65; N, 7.21.

1-Nitromethyl-3,4-dihydronaphthalene 4g. Reaction time: 24h; orange oil (20%), (eluent: ether / light petroleum 1:4); IR (neat): 1540, 1360 cm^{-1}; ^1H NMR: 2.3-2.4 (m, 2H), 2.80 (t, 2H, J=8), 5.24 (s, 2H), 6.28 (t, 1H, J=5), 7.16-7.19 (m, 2H). Anal. Calcd. for $C_{11}H_{11}NO_2$: C, 69.81; H, 5.86; N, 7.41. Found: C, 69.70; H, 5.79; N, 7.31.

6-Methoxy-1-nitromethyl-3,4-dihydronaphthalene 4h. Reaction time: 24h; yellow solid (20%), (eluent: ether / light petroleum 1:3), mp 58-60°C; IR ($CHCl_3$): 1550, 1370 cm^{-1}; ^1H NMR: 2.35-2.45 (m, 2H), 2.81 (t, 2H, J=8), 3.80 (s, 3H), 5.26 (s, 2H), 6.19 (t, 1H, J=5), 6.71-6.74 (m, 2H), 7.11-7.26 (m, 1H). Anal. Calcd. for $C_{12}H_{13}NO_3$: C, 65.73; H, 5.98; N, 6.39. Found: C, 65.66; H, 5.86; N, 6.30.

Preparation of the nitrocompounds 5(a-h). General procedure: a solution of the nitroolefines **4(a-h)** (18 mmol) and paraformaldehyde (6mmol) in MeOH (10 ml) was added to a cooled (0°C) solution of MeONa (from Na, 18mmol) in MeOH (10ml) and stirred for 20h at the same temperature. The solid sodium nitronate was filtered and suspended in ether (200ml). A solution of salicylic acid (18mmol) in ether (20ml) was added and the mixture heated at reflux for the appropriate time. The cooled solution was filtered, evaporated and the residue flash chromatographed.

(E)- and (Z)-3-Methyl-2-nitro-3-penten-1-ol 5a. Sodium nitronate: brown solid (mp 184°C with decomposition). Reaction time: 10h; yellow oil (89%), (eluent: ether / light petroleum 1:2). IR: 3360, 1540, 1370 cm^{-1}; ^1H NMR: E/Z=7/93; 1.67 (s, 3H), 1.70 (d, 3H, J=2), [1.76 (d, 3H, J=2), 1.80 (d, 3H, J=1) for (E) isomer], 2.34 (bs, 1H), 3.80 (dd, 1H, J=13, 4), 4.35 (dd, 1H, J=13, 9), 5.02 (dd, 1H, J=9, 4), [5.5-5.6 (dd, 1H, J=9, 4) for (E) isomer], 5.7-5.9 (m, 1H). Anal. Calcd. for $C_6H_{11}NO_3$: C, 49.63; H, 7.64; N, 9.65. Found: C, 49.54; H, 7.55; N, 9.59.

2-(Cyclopenten-1-yl)-2-nitro-1-ethanol and 2-cyclopentyl-2-nitro-2-ethen-1-ol 5b. Sodium nitronate: yellow solid (mp 156-158°C). Reaction time: 8h; yellow oils (42%), (eluent: ether / light petroleum 4:1); IR (neat): 3360, 1540, 1360 cm^{-1}; ^1H NMR: 1.8-2 (m, 2H), 2.3-2.5 (m, 4H), 3.91 (dd, 1H, J=12, 4), 4.34 (dd, 1H, J=12, 9), 5.28 (dd, 1H, J=9, 4), 5.91 (s, 1H). : 1.7-1.9 (m, 4H), 2.67 (t, 2H, J=5), 2.96 (t, 2H, J=5), 4.54 (s, 2H). Anal. Calcd. for $C_7H_{11}NO_3$: C, 53.48; H, 7.06; N, 8.91. Found: C, 53.40; H, 7.02; N, 8.86.

2-(Cyclohexen-1-yl)-2-nitro-1-ethanol 5c. Sodium nitronate: white solid (mp 158-160°C). Reaction time: 10h; yellow oil (80%), (eluent: ether / light petroleum 1:1). IR (neat): 3360, 1530, 1350 cm^{-1}; ^1H NMR: 1.5-1.7 (m, 4H), 2.0-2.2 (m, 4H), 3.82 (dd, 1H, J=12, 4), 4.35 (dd, 1H, J=12, 10), 4.98 (dd, 1H, J=10, 4), 5.9-6 (m, 1H). Anal. Calcd. for $C_8H_{13}NO_3$: C, 56.11; H, 7.66; N, 8.28. Found: C, 56.02; H, 7.56; N, 8.20.

3-Phenyl-2-nitro-3-buten-1-ol 5d. Sodium nitronate: yellow solid (mp 159-161°C). Reaction time: 20h; yellow oil (79%), (eluent: ether / petroleum ether 1:2); IR (neat): 3360, 1540, 1350 cm^{-1}; ^1H NMR: 2.76 (bs, 1H), 3.88 (dd, 1H, J=13, 3), 4.34 (dd, 1H, J=13, 10), 5.47 (s, 1H), 5.58 (s, 1H), 5.61 (dd, 1H, J=10, 3), 7.3-7.4 (m, 5H). Anal. Calcd for $C_{10}H_{11}NO_3$: C, 62.15; H, 5.74 ; N, 7.25. Found: C, 62.06; H, 5.63 ; N, 7.19.

3-(4-Nitrophenyl)-2-nitro-3-buten-1-ol 5e. Sodium nitronate: brown solid (mp 112°C with decomposition). Reaction time: 20h; yellow oil (37%), (eluent: ether / light petroleum 1:1). IR (neat): 3420, 1540, 1510, 1370, 1340 cm^{-1}; ^1H NMR: 3.6-3.7 (bs, 1H), 3.98 (dd, 1H, J=12, 3), 4.38 (dd, 1H, J=12, 9), 5.6 (dd, 1H, J=9, 3), 5.74 (s, 1H), 5.76 (s, 1H), 7.5-7.6 (m, 2H), 8.2-8.3 (m, 2H). Anal. Calcd. for $C_{10}H_{10}N_2O_5$: C, 50.41; H, 4.23; N, 11.76. Found: C, 50.33; H, 4.13; N, 11.65.

3-(4-Methoxyphenyl)-2-nitro-3-buten-1-ol 5f. Sodium nitronate: brown solid (mp 118-121°C). Reaction time: 20h; yellow oil (67%), (eluent: ether / light petroleum 1:2); IR (neat): 3440, 1360 cm^{-1}; ^1H NMR: 2.5-2.6 (bs, 1H), 3.82 (s, 3H), 3.89 (dd, 1H, J=12, 3), 4.35 (dd, 1H, J=12, 9), 5.38 (s, 1H), 5.52 (s, 1H), 5.6 (dd, 1H, J=9, 3), 6.85-6.95 (m, 2H), 7.3-7.4 (m, 2H). Anal. Calcd. for $C_{11}H_{13}NO_4$: C, 59.17; H, 5.87; N, 6.28. Found: C, 59.08; H, 5.76; N, 6.19.

2-(3,4-Dihydronapht-1-yl)-2-nitro-1-ethanol 5g. Sodium nitronate: pink solid (mp 161-163°C). Reaction time: 8h; yellow oil (92%), (eluent: ether / light petroleum 1:1); IR (neat): 3380, 1540, 1350 cm^{-1}; ^1H NMR: 2.2-2.4 (m, 2H), 2.75 (t, 2H, J=8), 3.93 (dd, 1H, J=13, 3), 4.47 (dd, 1H, J=13, 10), 5.75 (dd, J=10, 3), 6.29 (t, 1H, J=5), 7.1-7.4 (m, 4H). Anal. Calcd. for $C_{12}H_{13}NO_3$: C, 65.73; H, 5.98; N, 6.39. Found: C, 65.66; H, 5.88; N, 6.27.

2-(6-Methoxy-3,4-dihydronapht-1-yl)-2-nitro-1-ethanol 5h. Sodium nitronate: yellow solid (mp 87-88°C). Reaction time: 20h; yellow oil (76%), (eluent: ether / light petroleum 1: 2); IR (neat): 3380, 1530, 1340 cm^{-1}; ^1H NMR: 1.6-1.8 (bs, 1H), 2.2-2.4 (m, 2H), 2.73 (t, 2H, J=8), 3.81 (s, 3H), 3.95 (dd, 1H, J=14, 3), 4.47 (dd, 1H, J=14, 10), 5.7 (dd, J=10, 3), 6.14 (t, 1H, J=5), 6.75-6.85 (m, 2H), 7.26 (t, 1H, J=3). Anal. Calcd. for $C_{13}H_{15}NO_4$: C, 62.63; H, 6.07; N, 5.62. Found: C, 62.57; H, 5.97; N, 5.53.

Preparation of the nitroderivatives 6(a-h). General procedure: to ice cooled Ac_2O (2.5 ml) containing 5 drops of 98% H_2SO_4, the nitroalcohol **5(a-h)** was added and the solution stirred at room temperature until completion (20 min.). Ether (10 ml) was added, the mixture washed with saturated aqueous $NaHCO_3$ and dried. The solvent was evaporated to give a residue which was used in the next step without purification.

Cycloaddition with methyl acrylate. General procedure: a solution of the nitroacyl derivatives **1** and **6b** (2mmol) and methyl acrylate (60mmol) in benzene (20ml) containing sodium acetate (0.3 g) was heated at reflux for the appropriate time. The solvent was evaporated and the residue, dissolved in ether (20 ml), was washed with saturated aqueous $NaHCO_3$. The organic phase was separed, dried and concentrated and the residue purified by flash column chromatography.

Methyl 3-methyl-4-nitro-3-cyclohexen-1-carboxylate 8. Reaction time: 72h; yellow oil (98%), (eluent: ether / light petroleum 1:2); IR (neat): 1730, 1500, 1330 cm^{-1}; ^1H NMR: 1.6-2.9 (m, 7H), 2.08 (s, 3H), 3.72 (s, 3H). Anal. Calcd. for $C_9H_{13}NO_4$: C, 54.25; H, 6.58; N, 7.03. Found: C, 54.15; H, 6.50; N, 6.96.

***(exo/endo)*-Methyl 5-nitrobicyclo-[4.3.0]-5-nonen-carboxylate 9 and 10.** Reaction time: 2h; yellow oils (71%), (eluent: ether / light petroleum 1:4); IR (neat): 1730, 1500, 1330 cm^{-1}; ^1H NMR: *endo/exo* ratio=76/24; 1.2-3.2 (m, 12H), 3.6 (s, 3H) [3.7 (s, 3H) for the *exo* isomer]. Anal. Calcd. for $C_{11}H_{15}NO_4$: C, 58.64; H, 6.72; N, 6.22. Found: C, 58.57; H, 6.65; N, 6.19.

Cycloaddition with cyclopentadiene. General procedure: a solution of the nitroacyl derivatives **1** and **6(b-f,h)** (2mmol.) and freshly distilled cyclopentadiene (1ml) in benzene (5ml) was heated at reflux for the appropriate time (TLC monitoring). The solvent was evaporated and the residue purified by flash column chromatography (eluent: petroleum ether; then ether / petroleum ether 1:9). The mixture of *exo/endo* cycloadducts in toluene was heated at 120 °C in a sealed tube to afford the corresponding rearranged products.

***(exo/endo)*-6-(1-Propen-2-yl)-6-nitro-bicyclo-[2.2.1]-hept-2-ene 11/12 and 4-methyl-3-nitrobicyclo-[4.3.0]-3,7-nonadiene 13.** Reaction time: 72h; yellow oils, **11+12** (64%); **13**, (26%).; **11/12**: IR (neat): 1530, 1340 cm^{-1}; ^1H NMR: 12/11 ratio=70/30; 1.8 (s, 3H), 2 (m, 2H), 2.5 (dd, 1H, J=16, 3), 2.7 (dd, 1H, J=16, 3), 2.95 (s, 1H), 3.65 (s, 1H) [3.8 (s, 1H) for **11**], 5.15 (s, 1H) [5.1 (s, 1H) for **11**], 5.3 (s, 1H), 6 (m, 1H), 6.4 (m, 1H). The mixture of **11** and **12** in toluene was heated for 3 days to furnish **13** (46%): **13**: IR (neat): 1500, 1330 cm^{-1}; ^1H NMR: 2-2.2 (m, 1H), 2.15 (s, 3H), 2.4-2.7 (m, 6H), 3-3.1 (s, 1H), 5.5 (m, 1H), 5.7 (m, 1H). Anal. Calcd. for . $C_{10}H_{13}NO_2$: C, 67.00; H, 7.32; N, 7.82. Found: C, 66.90; H, 7.27; N, 7.72.

***(exo/endo)*-6-(Cyclopenten-1-yl)-6-nitro-bicyclo-[2.2.1]-hept-2-ene 15 and (5aβ,8aβ,8bβ)-4-nitro-1,2,3,5,5a,6,8a,8b-octahydro-as-indacene 16.**

Reaction time: 24h; yellow oils, **15** (55%), **16** (29%). The mixture of *exo* and *endo* **15** was heated for 3 days to give **16** (52%). **15**: IR (neat): 1530, 1340 cm^{-1}; ^1H NMR: *exo/endo* ratio=80/20; 1.6-1.7 (m, 2H), 1.8-2 (m, 3H), 2.02 (dd, 1H, J=17, 2), 2.2-2.5 (m, 4H), 2.95 (s, 1H), 3.59 (s, 1H) [3.8 (s, 1H) for the *endo* isomer], 5.3 (s, 1H), 5.95-6.05 (m, 2H), 6.35 (dd, 1H, J=6, 3). **16**: IR (neat): 1500, 1330 cm^{-1}; ^1H NMR: 1.6-1.8 (m, 2H), 1.9-2.1 (m, 4H), 2.3-2.4 (m, 1H), 2.5-2.7 (m, 2H), 2.9-3.1 (m, 2H), 3.2-3.3 (m, 1H), 5.5-5.6 (m, 1H), 5.6- 5.7 (m, 1H). Anal. Calcd. for Anal. Calcd. for $C_{12}H_{15}NO_2$: C, 70.21; H, 7.37; N, 6.83. Found: C, 70.11; H, 7.27; N, 6.74.

***(exo/endo)*-6-(Cyclohexen-1-yl)-6-nitro-bicyclo-[2.2.1]-hept-2-ene 17 and (3aβ,9aβ,9bβ)-5-nitro-3a,4,6,7,8,9,9a,9b-octahydro-3H-benz [e] indene 18.** Reaction time: 72h; yellow oils, **17**, (65%), **18** (19%). The mixture of *exo* and *endo* **17** was heated for 72h to give **18** (55%). **17**: IR (neat): 1520, 1340 cm^{-1}; ^1H NMR: *exo/endo* ratio=85/15; 1.5-1.7 (m, 8H), 1.75-1.95 (m, 1H), 2.01 (dd, 1H, J=14, 6), 2.1-2.2 (m, 2H), 2.45 (dd, 1H, J=14, 4), 2.93 (s, 1H) [3 (s, 1H), 3.5 (s, 1H) for the *endo* isomer], 3.65 (d, 1H, J=1), 5.95 (dd, 1H, J=6, 3), 6-6.1 (m, 1H), 6.38 (dd, 1H, J=6, 3). **18**: IR (neat): 1500, 1330 cm^{-1}; ^1H NMR: 1.4-2 (m, 6H), 2.1-2.4 (m, 8H), 3.2-3.3 (m, 1H), 59-6 (m, 1H), 6-6.1 (m, 1H). Anal. Calcd. for $C_{13}H_{17}NO_2$: C, 71.19; H, 7.82; N, 6.39. Found: C, 71.09; H, 7.73; N, 6.31.

***(exo/endo)*-6-(1-Phenyl-1-ethen-1-yl)-6-nitro-bicyclo-[2.2.1]-hept-2-ene 19 and 4-phenyl-3-nitro-bicyclo-[4.3.0]-3,7-nonadiene 20.** Reaction time: 24h; yellow oils, **19** (65%), **19+20** (23%). The mixture of *exo* and *endo* **19** was heated for 72h to give **20** (60%). **19**: IR (neat): 1520, 1340 cm^{-1}; ^1H NMR:

exo/endo ratio=89/11; 1.6-1.7 (m, 2H), 2.17 (dd, 1H, J=13, 4), 2.53 (dd, 1H, J=14, 3), 2.96 (s, 1H), 3.73 (d, 1H, J=1) [3.9 (s, 1H), 5.4 (s, 1H) for the *endo* isomer], 5.49 (s, 1H) [5.65 (s, 1H) for the *endo* isomer], 5.83 (s, 1H), 5.99 (dd, 1H, J=6, 3), 6.42 (dd, 1H, J=6, 3), 7.1-7.4 (m, 5H). **20**: IR (neat): 1500, 1330 cm^{-1}; ^1H NMR: 2.2 (dm, 1H), 2.4 (dd, 1H, J=17, 6), 2.6-2.8 (m, 4H), 2.8-3 (m, 1H), 3.1-3.3 (m, 1H), 5.5-5.6 (m, 1H), 5.7-5.8 (m, 1H), 7.1-7.2 (m, 2H), 7.3-7.4 (m, 3H). Anal. Calcd. for $C_{15}H_{15}NO_2$: C, 74.65; H, 6.27; N, 5.81. Found: C, 74.54; H, 6.19; N, 5.67.

(*exo/endo*)-6-(1-(4-Nitrophenyl)-1-ethen-1-yl)-6-nitro-bicyclo-[2.2.1]-hept-2-ene 21 and 4-(4-nitrophenyl)-3-nitro-bicyclo-[4.3.0]-3,7-nonadiene 22. Reaction time: 24h; yellow solid, **21**, (35%), yellow oil, **22**, (13%).The mixture of *exo* and *endo* **21** was heated for 24h to give **22** (84%). *Exo*-**21**: mp 99-101°C; IR ($CHCl_3$): 1540, 1340 cm^{-1}; ^1H NMR: 1.7-1.8 (m, 2H), 1.84 (d, 1H, J=3), 2.87 (d, 1H, J=3), 2.93 (s, 1H), 3.91 (d, 1H, J=2), 5.56 (s, 1H), 5.8-5.9 (m, 1H), 6.3 (dd, 1H, J=4, 2), 7.3-7.4 (m, 2H, 8.1-8.2 (m, 2H); **21**: m.p.: 116-119 °C; IR ($CHCl_3$): 1540, 1340 cm^{-1}; ^1H NMR: 1.7-1.8 (m, 2H), 2.15 (dd, 1H, J=16, 3), 2.6 (dd, 1H, J=16, 3), 3 (s, 1H), 3.73 (s, 1H), 5.61 (s, 1H), 5.9-6 (m, 1H), 6.5 (dd, 1H, J=4, 2), 7.4-7.5 (m, 2H), 8.1-8.2 (m, 2H); **22**: IR (neat): 1500, 1340 cm^{-1} ^1H NMR: 2.2 (dm, 1H), 2.4 (dd, 1H, J=17, 6), 2.6-2.8 (m, 4H), 2.9-3 (m, 1H), 3.2-3.3 (m, 1H), 5.5-5.6 (m, 1H), 5.8-5.9 (m, 1H), 7.3-7.4 (m, 1H), 8.2-8.3 (m, 1H). Anal. Calcd. for $C_{15}H_{14}N_2O_4$: C, 62.92; H, 4.93; N, 9.79. Found: C, 62.85; H, 4.83; N, 9.66.

(*exo/endo*)-6-(1-(4-Methoxyphenyl)-1-ethen-1-yl)-6-nitro-bicyclo-[2.2.1]-hept-2-ene 23 and 4-(4-methoxyphenyl)-3-nitro-bicyclo-[4.3.0]-3,7-nonadiene 24. Reaction time: 24h, yellow oils, **23** (27%), **23+24** (13%). The mixture of *exo* and *endo* **23** was heated for 24h to furnish **24** (76%). **23**: IR (neat): 1530, 1370 cm^{-1}; ^1H NMR: *exo/endo* ratio=90/10; 1.64 (s, 2H), 2.2 (dd, 1H, J=16, 3), 2.6 (dd, 1H, J=16, 3), 3 (s, 1H), 3.7 (s, 1H), 3.80 (s, 3H), 5.46 (s, 1H), 5.75 (s, 1H), 5.9-6 (m, 1H), 6.4-6.5 (m, 1H), 6.8-6.9 (m, 2H), 7.1-7.2 (m, 2H). **24**: IR (neat): 1500, 1330 cm^{-1}; ^1H NMR: 2.2 (dm, 1H), 2.4-(dd, 1H, J=16, 4), 2.6-2.9 (m, 5H), 3.1-3.2 (m, 1H), 3.80 (s, 3H), 5.5-5.6 (m, 1H), 5.7-5.8 (m, 1H), 7-7.1 (m, 2H), 7.2-7.3 (m, 2H). Anal. Calcd. for $C_{16}H_{17}NO_3$: C, 70.82; H, 6.32; N, 5.16. Found: C, 70.72; H, 6.21; N, 5.06.

***Exo*-6-(6-Methoxy-3,4-dihydronaphth-1-yl)-6-nitro-bicyclo-[2.2.1]-hept-2-ene 27 and (8β,13β,14β)-3-methoxy-11-nitro-6,7,8,13,14,17-hexahydro-12H-cyclopenta [a] phenantrene 25.** Reaction time: 24h; orange oils,**27** (52%), **25** (7%). **27**: IR (neat): 1520, 1350 cm^{-1}; ^1H NMR: 1.59 (s, 2H), 2.1 (dd, 1H, J=16, 3), 2.3-2.4 (m, 2H), 2.6-2.8 (m, 3H), 3 (s, 1H), 3.78 (s, 3H), 3.84 (s, 1H), 5.9 (dd, 1H, J=6, 3), 6.5-6.7 (m, 3H). **25**: IR (neat): 1500, 1340 cm^{-1}; ^1H NMR: 2-2.1 (m, 2H), 2.3-3 (m, 7H), 3.2-3.3 (m, 1H), 3.79 (s, 3H), 5.4-5.5 (m, 1H), 5.6-5.7 (m, 1H), 6.6-6.8 (m, 3H). Anal. Calcd. for $C_{18}H_{19}NO_3$: C, 72.69; H, 6.44; N, 4.71. Found: C, 72.56; H, 6.32; N, 4.65.

1-(1'-Hydroxycyclopent-2'-en-5'yl) methyl-7-methoxy-4,5-dihydro-naphth [1,2-d]-[1,2]-oxazole 28. This compound was obtained in 36% yield as orange oil refluxing **27** in toluene for 96h; IR (neat): 3400, 1610 cm^{-1}; ^1H NMR: 2.3-2.8 (m, 5H), 3-3.2 (m, 4H), 3.3 (dd, 1H, J=14, 9), 3.81 (s, 3H), 4.7-4.8 (m, 1H), 5.9-6 (m, 1H), 6-6.1 (m, 1H), 6.7-6.8 (m, 2H), 7.2-7.3 (m, 1H). Anal. Calcd. for $C_{17}H_{19}NO_3$: C, 71.54; H, 6.72; N, 4.91. Found: C, 71.46; H, 6.67; N, 4.82.

Cycloaddition with ethyl vinyl ether. General procedure; a cooled (0°C) solution of the nitroacyl derivative, **1** and **6(a-h)**, (5 mmol) in ethyl vinyl ether (10 ml) containing triethylamine (36 drops) was stirred for the appropriate time. The solvent was evaporated and the residue, dissolved in ether (20 ml), was washed with water and saturated aqueous $NaHCO_3$. The organic phase was separed, dried and concentrated and the residue purified by flash column chromatography.

6-Ethoxy-3-(propen-2-yl)-5,6-dihydro-4H-1,2-oxazin-2-oxide 31. Reaction time: 4h; yellow oil (87%) after flash chromatography (eluent: ether / light petroleum 1:3). IR (neat): 1600, 1570, 1550 cm^{-1}; ^1H NMR: 1.24 (t, 3H, J=7), 1.8-2.2 (m, 2H), 2.07 (d, 3H, J=1), 2.5 (dd, 1H, J=9, 5), 2.6 (dd, 1H, J=11, 6), 3.68 (dq, 1H, J=11, 9), 4.03 (dq, 1H, J=11, 9), 5.34 (s, 1H), 5.36 (dd, 1H, J=3, 2), 5.79 (s, 1H). Anal. Calcd for $C_9H_{15}NO_3$: C, 58.35; H, 8.17; N, 7.56. Found: C, 58.26; H, 8.07; N, 7.50.

6-Ethoxy-3-(2-buten-2-yl)-5,6-dihydro-4H-1,2-oxazin-2-oxide 31a. Reaction time 22h; yellow oil (44%), (eluent: ether / light petroleum 1:1); IR (neat): 1570, 1550 cm^{-1}; ^1H NMR: 1.24 (t, 3H, J=7), 1.77 (d, 3H, J=6), 1.9-2 (m, 1H), 1.92 (s, 3H), 2-2.2 (m, 1H), 2.47 (dd, 1H, J=9, 5), 2.6 (dd, 1H, J=12, 7), 3.67 (dq, 1H, J=10, 7), 4.03 (dq, 1H, J=10, 7), 5.34 (dd, 1H, J=4, 3), 6.08 (q, 1H, J=6). Anal. Calcd for $C_{10}H_{17}NO_3$: C, 60.26; H, 8.60; N, 7.03. Found: C, 60.21; H, 8.51; N, 6.97.

6-Ethoxy-3-(1-cyclopenten-1-yl)-5,6-dihydro-4H-1,2-oxazin-2-oxide 31b. Reaction time: 3h; yellow solid (89%), (eluent: ether / light petroleum 2:1), mp 64-66°C; IR (neat): 1590, 1550 cm^{-1}; ^1H NMR: 1.22 (t, 3H, J=8), 1.8-2.2 (m, 4H), 2.5-2.7 (m, 6H), 3.66 (dq, 1H, J=10, 6), 4.02 (dq, 1H, J=10, 6), 5.34 (dd, 1H, J=6, 4), 6.88 (s, 1H). Anal. Calcd for $C_{11}H_{17}NO_3$: C, 62.52; H, 8.12; N. 6.63. Found: C, 62.43; H, 8.06; N, 6.53.

6-Ethoxy-3-(1-cyclohexen-1-yl)-5,6-dihydro-4H-1,2-oxazin-2-oxide 31c. Reaction time: 72h; yellow oil (78%), (eluent: ether / light petroleum 1:1); IR (neat): 1560 cm^{-1}; ^1H NMR: 1.23 (t, 3H, J=7), 1.6-1.8 (m, 4H), 1.8-2 (m, 1H), 2-2.1 (m, 1H), 2.15-2.25 (m, 2H), 2.3-2.4 (m, 2H), 2.45 (dd, 1H, J=9, 5), 2.6 (dd, 1H, J=12, 7), 3.67 (dq, 1H, J=11, 9), 4.5 (dq, 1H, J=11, 9), 5.34 (dd, 1H, J=4, 3), 6.54 (m, 1H). Anal. Calcd for $C_{12}H_{19}NO_3$: C, 63.96; H, 8.52; N, 6.22. Found: C, 63.88; H, 8.49; N, 6.12.

6-Ethoxy-3-(1-phenylethen-1-yl)-5,6-dihydro-4H-1,2-oxazin-2-oxide 31d. Reaction time: 24h; yellow oil (94%), (eluent: ether / light petroleum 1:1); IR (neat): 1580 cm^{-1}; ^1H NMR: 1.30 (t, 3H, J=7), 1.9-2.05 (m, 1H), 2.1-2.3 (m, 1H), 2.4-2.7 (m, 2H), 3.7 (dq, 1H, J=11, 9), 4.1 (dq, 1H, J=11, 9), 5.42 (dd, 1H, J=4, 3), 5.81 (s, 1H), 5.87 (s, 1H), 7.3-7.4 (m, 5H). Anal. Calcd for $C_{14}H_{17}NO_3$: C, 67.98; H, 6.93; N, 5.67. Found: C, 67.86; H, 6.76; N, 5.58.

6-Ethoxy-3-[1-(4-nitrophenyl)-ethen-1-yl]-5,6-dihydro-4H-1,2-oxazin-2-oxide 31e. Reaction time: 48h; brown oil (29%), (eluent: ether / light petroleum 2:1); IR (neat): 1590, 1500, 1340 cm^{-1}; ^1H NMR: 1.32 (t, 3H, J=7), 2-2.4 (m, 2H), 2.6-2.8 (m, 2H), 3.75 (dq, 1H, J=10, 7), 4.07 (dq, 1H, J=10, 7), 5.46 (dd, 1H, J=4, 2), 5.86 (s, 1H), 5.90 (s, 1H), 7.5-7.6 (m, 2H), 8.2-8.4 (m, 2H). Anal. Calcd for $C_{14}H_{16}N_2O_5$: C, 57.51; H, 5.52; N, 9.59. Found: C, 57.41; H, 5.43; N, 9.51.

6-Ethoxy-3-[1-(4-methoxyphenyl)-ethen-1-yl]-5,6-dihydro-4H-1,2-oxazin-2-oxide 31f. Reaction time: 18h; yellow solid (91%), (eluent: ether / light petroleum 1:1); mp 59-61°C; IR ($CHCl_3$): 1590, 1500 cm^{-1}; ^1H NMR: 1.31 (t, 3H, J=7), 1.9-2.1 (m, 1H), 2.1-2.3 (m, 1H), 2.5-2.8 (m, 2H), 3.75 (dq, 1H, J=11, 9), 3.81 (s, 3H), 4.1 (dq, 1H, J=11, 9), 5.43 (dd, 1H, J=6, 3), 5.74 (s, 1H), 6.8-6.9 (m, 2H), 7.5-7.6 (m, 2H). Anal. Calcd for $C_{15}H_{19}NO_4$: C, 64.95; H, 6.91; N, 5.05. Found: 64.86; H, 6.77; N, 5.01.

6-Ethoxy-3-(3,4-dihydronaphth-1-yl]-5,6-dihydro-4H-1,2-oxazin-2-oxide 31g. Reaction time: 24h; white solid (91%), (eluent: ether / light petroleum 1:1), mp 85-87°C; IR ($CHCl_3$): 1590, 1470 cm^{-1}; ^1H NMR: 1.29 (t, 3H, J=7), 1.8-2.2 (m, 2H), 2.25-2.45 (m, 2H), 2.5-2.8 (m, 4H), 3.71 (dq, 1H, J=10, 7), 4.07 (dq, 1H, J=10, 7), 5.35 (dd, 1H, J=4, 2), 6.21 (t, 1H, J=4), 7-7.2 (m, 4H). Anal. Calcd for $C_{16}H_{19}NO_3$: C, 70.29; H, 7.01; N, 5.13. Found: C, 70.18; H, 6.95; N, 5.09.

6-Ethoxy-3-(6-methoxy-3,4-dihydronaphth-1-yl]-5,6-dihydro-4H-1,2-oxazin-2-oxide 31h. Reaction time: 24h; oil (89%), (eluent: ether / light petroleum 1:1); IR (neat): 1590, 1470 cm^{-1}; ^1H NMR: 1.37 (t, 3H, J = 7), 2-2.3 (m, 2H), 2.3-2.48 (m, 2H), 2.5-2.8 (m, 4H), 3.75 (m, 1H), 3.8 (s, 3H), 4.15 (m, 1H), 5.44 (m, 1H), 6.14 (t, 1H, J = 4.6), 6.72 (m, 2H), 6.96 (d, 1H, J = 9.3). Anal. Calcd for $C_{17}H_{21}NO_4$: C, 67.31; H, 6.98; N, 4.62. Found: C, 67.21; H, 6.88; N, 4.54.

Preparation of the 1,2-oxazol-3-propionaldehydes 34(a-h). General procedure: a solution of **31(a-h)** (2mmol) in toluene (10ml) was heated at reflux for the appropriate time. The solvent was evaporated and the residue purified by flash chromatography to give the corresponding aldehydes.

4,5-Dimethyl-1,2-oxazol-3-propionaldehyde 34a. Reaction time: 3.5h; yellow oil (39%), (eluent: ether / light petroleum 1:1); IR (neat): 1710, 1620 cm^{-1}; ^1H NMR: 1.70 (s, 3H), 2.29 (s, 3H), 2.8-3 (m, 4H), 9.87 (s, 1H). Anal. Calcd. for $C_8H_{11}NO_2$: C, 62.71; H, 7.24; N, 9.15. Found: C, 62.63; H, 7.16; N, 9.09.

Cyclopenta-[c]-1,2-oxazol-3-propionaldehyde 34b. Reaction time: 6h; yellow oil (50%), (eluent: ether / light petroleum 1:1); IR (neat): 1710, 1620 cm^{-1}; ^1H NMR: 1.6-1.9 (m, 2H), 2.3-2.4 (m, 2H), 2.6-2.7 (m, 2H), 2.8-3 (m, 4H), 9.87 (s, 1H). Anal. Calcd. for $C_9H_{11}NO_2$: C, 65.44; H, 6.71; N, 8.48. Found: C, 65.37; H, 6.65; N, 8.44.

Tetrahydro-benzo-[1,2-d]-1,2-oxazol-3-propionaldehyde 34c. A solution of **35** (1mmol) in EtOH (15ml) containing 5% H_2SO_4 (4 ml) was stirred at room temperature for 24h. The solvent was evaporated, the residue dissolved in ether (15 ml) and washed with saturated aqueous $NaHCO_3$. The organic phase was dried, concentrated and the residue purified by flash chromatography (eluent: ether / light petroleum 1:1). Yellow oil.(43%); IR (neat): 1710, 1630 cm^{-1}; ^1H NMR: 1.6-1.9 (m, 4H), 2.3-2.4 (m, 2H), 2.6-2.7 (m, 2H), 2.8-3 (m, 4H), 9.87 (s, 1H). Anal. Calcd. for $C_{10}H_{13}NO_2$: C, 67.00; H, 7.32; N, 7.82. Found: C, 66.87; H, 7.25; N, 7.74.

4-Phenyl-1,2-oxazol-3-propionaldehyde 34d. Reaction time: 24h; amber coloured oil (56%), (eluent: ether / light petroleum 1: 1); IR (neat): 1710, 1600, 1580 cm^{-1}; ^1H NMR: 2.9-3.2 (m, 4H), 7.3-7.5 (m, 5H), 8.42 (s, 1H), 9.84 (s, 1H). Anal. Calcd. for $C_{12}H_{11}NO_2$: C, 71.61; H, 5.51; N, 6.96. Found: C, 71.56; H, 5.43; N, 6.87.

4-(4-Nitrophenyl)-1,2-oxazol-3-propionaldehyde 34e. Reaction time: 24h; brown solid (41%), (eluent: ether / light petroleum 3:1), mp 83-85°C; IR ($CHCl_3$): 1710, 1600, 1580 cm^{-1}; ^1H NMR: 3-3.1 (m, 4H), 7.5-7.6 (m, 2H), 8.2-8.3 (m, 2H), 8.59 (s, 1H), 9.87 (s, 1H). Anal. Calcd. for $C_{12}H_{10}N_2O_4$: C, 58.52; H, 4.10; N, 11.38. Found: C, 58.44; H, 4.01; N, 11.28.

4-(4-Methoxyphenyl)-1,2-oxazol-3-propionaldehyde 34f. Reaction time: 7h; orange oil (36%), (eluent: ether / light petroleum 1:1); IR (neat): 1710, 1590, 1500 cm^{-1}; ^1H NMR: 2.9-3.1 (m, 4H), 3.84 (s, 3H), 6.9-7 (m, 2H), 7.3-7.4 (m, 2H), 8.36 (s, 1H), 9.83 (s, 1H). Anal. Calcd. for $C_{13}H_{13}NO_3$: C, 67.51; H, 5.67; N, 6.06. Found: C, 67.44; H, 5.57; N, 6.01.

Dihydro-naphtho-[1,2-d]-1,2-oxazol-3-propionaldehyde 34g. Reaction time: 2h; white solid (61%), mp 57-59°C, (eluent: ether / light petroleum 2:1); IR ($CHCl_3$): 1710, 1610, 1500 cm^{-1}; ^1H NMR: 2.9-3.3 (m, 8H), 7.1-7.4 (m, 4H), 9.94 (s, 1H). Anal. Calcd. for $C_{14}H_{13}NO_2$: C, 73.98; H, 5.77; N, 6.17. Found: C, 73.76; H, 5.65; N, 6.05.

6-Methoxy-dihydro-naphtho-[1,2-d]-1,2-oxazol-3-propionaldehyde 34h. Reaction time: 6h; oil (65%), (eluent: ether / light petroleum 1:1); IR (neat): 1710, 1610, 1500 cm^{-1}; ^1H NMR: 2.95-3.08 (m, 6H), 3.22 (m, 2H), 3.8 (s, 3H), 6.82 (m, 2H), 7.29 (d, 1H, J = 8.2), 9.91 (s, 1H). Anal. Calcd. for $C_{15}H_{15}NO_3$: C, 70.02; H, 5.88; N, 5.44. Found: C, 69.95; H, 5.79; N, 5.36.

Thermal rearrangement of the oxazine 31c. A solution of **31c** in toluene was refluxed for 3 days. After usual work-up, the residue was submitted to column chromatography (eluent : ether / light petroleum 1:1) to afford a mixture of compounds **35**, **36** and **37**.

Aldehydo acetal 35, (18%); IR (neat): 1710, 1450 cm^{-1}; ^1H NMR: 1.21 (t, 3H, J=8), 1.4-2.2 (m, 16H), 2.3-2.5 (m, 2H), 2.5-2.7 (m, 2H), 2.8-3 (m, 4H), 3.4-3.7 (m, 2H), 3.9 (dq, 1H, J=12, 8), 4.95 (dd, 1H, J=12, 4), 9.87 (s, 1H); ^{13}C NMR: 14.5 ($\underline{C}H_3CH_2O$), 17.2 and 18.5 ($CCH_2\underline{C}H_2\underline{C}H_2\underline{C}H_2C$), 19.5, 20.5, 21.5 and 21.7 ($OC\underline{C}H_2\underline{C}H_2\underline{C}H_2\underline{C}H_2CHO$), 21.8 ($OOCH\underline{C}H_2CH_2$), 21.9 ($\underline{C}H_2\underline{C}H_2C{=}CO$), 23 ($CH_2\underline{C}H_2C{=}CC{=}N$), 27.6 ($CH_2\underline{C}H_2C{=}N$), 36.9 ($\underline{C}H_2CH_2CH(O)$, 39.9 ($CH_2\underline{C}H_2CH(O)$, 63.8 ($CH_3\underline{C}H_2O$), 83.8 ($ON{=}C\underline{C}O$), 85.7 ($O\underline{C}HCO$), 95.9 ($O\underline{C}HOC_2H_5$), 110.9 ($CH_2\underline{C}{=}CON$), 159.5 ($C{=}\underline{C}O$), 162.6 ($CH_2\underline{C}{=}NO$), 167.2 ($\underline{C}C{=}NO$), 200 ($CH_2CH_2\underline{C}H(O)$). Anal. Calcd. for $C_{22}H_{32}N_2O_5$: C, 65.31; H, 7.98; N, 6.98. Found: C, 65.28; H, 7.79; N, 6.90;

8-Ethoxy-hexahydro-1,2-benzisoxazolo[2,3-b]oxazine 36, (12%) ; IR (neat): 1440 cm^{-1}; ^1H NMR: 1.20 (t, 3H, J=8), 1.4-2.4 (m, 8H), 2.6-3 (m, 4H), 3.4-3.6 (m, 2H), 3.86 (dq, 1H, J=11, 6), 4.8-4.9 (m, 1H); ^{13}C NMR: 14.9 ($\underline{C}H_3$), 20.2 ($CH_2\underline{C}H_2CH_2$), 20.5 ($CH_2\underline{C}H_2CH_2$), 22.2 ($CH_2\underline{C}H_2CHO$), 23.8 ($CH_2\underline{C}H_2CHOO$), 32.3 ($CH_2\underline{C}H_2CCH$), 38.5 ($CH_2\underline{C}H_2CCN$), 64 ($CH_3\underline{C}H_2O$), 85.2 ($CH_2\underline{C}{=}CN$), 87 ($CH_2\underline{C}HON$), 98.6 ($CH_2\underline{C}HOO$), 164.9 ($CH_2\underline{C}N$). Anal. Calcd. for $C_{12}H_{19}NO_3$: C, 63.96; H, 8.51; N, 6.22. Found: C, 63.85; H, 8.39; N, 6.16;

5,6,7,7a-Tetrahydro-1,2-benzisoxazole-3-propionaldehyde 37, (20%) ; IR (neat): 1710 cm^{-1}; ^1H NMR: 2.2-3 (m, 10H), 4.7-4.8 (m, 1H), 5.8-5.9 (m, 1H), 9.86 (s, 1H); ^{13}C NMR: 17.4 ($CH_2\underline{C}H_2CH_2$), 18.5 ($CH_2\underline{C}H_2CHO$), 29.1 ($CH_2\underline{C}H_2CH$), 26.8 ($\underline{C}H_2C{=}N$), 39.5 ($CH(O)\underline{C}H_2CH_2$), 79.9 ($CH_2\underline{C}HO$), 121.8 ($CH_2\underline{C}H{=}C$), 141 ($CH\underline{C}{=}CH$), 156.2 ($C\underline{C}{=}N$), 200.5 ($\underline{C}H(O)CH_2CH_2$). Anal. Calcd. for $C_{10}H_{13}NO_2$: C, 67.02; H, 7.31; N, 7.82. Found: C, 66.95; H, 7.29; N, 7.76.

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